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Microbiological Quality of Indoor Air in University Libraries

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PEER REVIEW

Peer reviewer

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Comments

This study evaluated the indoor air quality of the eight different libraries through colony forming count method using both bacterial and fungal specific media. This is a simple and conventional way of microbial air quality assessment.
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ABSTRACT

Objective: To evaluate the concentration of bacteria and fungi in the indoor environment of Jimma University libraries, so as to estimate the health hazard and to create standards for indoor air quality control.

Methods: The microbial quality of indoor air of eight libraries of Jimma University was determined. The settle plate method using open Petri-dishes containing different culture media was employed to collect sample twice daily. Isolates were identified according to standard methods.

Results: The concentrations of bacteria and fungi aerosols in the indoor environment of the university libraries ranged between 367-2595 CFU/m^3. According to the sanitary standards classification of European Commission, almost all the libraries indoor air of Jimma University was heavily contaminated with bacteria and fungi. In spite of their major source difference, the average fungi density found in the indoor air of libraries did appear to follow the same trend with bacterial density (P=0.001). The bacteria isolates included *Micrococcus* sp., *Staphylococcus aureus*, *Streptococcus pyogenes*, *Bacillus* sp. and *Neisseria* sp. while *Cladosporium* sp., *Alternaria* sp., *Penicillium* sp. and *Aspergillus* sp. were the most isolated fungi.

Conclusions: The indoor air of all libraries were in the range above highly contaminated according to European Commission classification and the most isolates are considered as potential candidates involved in the establishment of sick building syndromes and often associated with clinical manifestations like allergy, rhinitis, asthma and conjunctivitis. Thus, attention must be given to control those environmental factors which favor the growth and multiplication of microbes in indoor environment of libraries to safeguard the health of users and workers.

KEYWORDS

Indoor air, Open-plate technique, Microbiological assessment, Bacteria, Fungi, Sedimentation technique

1. Introduction

How safe is the air in your surrounding environment that you spend much of your time? Indoor environments are fundamental environmental factors capable of impacting health. Air quality of indoor environments is one of the main factors affecting health, wellbeing and productivity of people. One of the problems of indoor air quality is affected by the presence of microorganisms which include bacteria, moulds and viruses[1,2] and people spends 80%-90% of their time in indoors environments[3] by breathing on average 14 m^3 of air per day[4]. These makes people highly exposed to indoor air environments. As of these, in recent years there has been a growing interest in indoor

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microbe studies[1-3,5-13].

The activity of people and equipment within the indoor environments is thought to be the principal factor contributing to the buildup and spread of airborne microbial contamination[5,6,14]. Particular activities like talking, sneezing, coughing, walking and washing can generate airborne biological particulate matter. Food stuffs, house plants and flower pots, house dust, textiles, carpets, wood material and furniture stuffing, occasionally release various fungal spores into the air[11,15].

Moreover, the environmental factors mainly include temperature, humidity, air exchange rate, air movement, building structures and location, poor design, ventilation system as well as interior or redesign which enhance microorganism's growth and multiplication in the indoor atmosphere[2,7,16].

A review made by WHO on the number of epidemiological studies showed that, there is sufficient evidence for an association between indoor dampness-related factors and a wide range of effects on respiratory health, including asthma development, asthma exacerbation, current asthma, respiratory infections, upper respiratory tract symptoms, cough, wheeze and dyspnoea[1].

Thus microbiological air quality is an important criterion that must be taken into account when indoor workplaces are designed to provide a safe environment. This study provides information on the current concentration of microorganisms and describes bacterial and fungal loads for different libraries of Jimma University. Moreover, co-existence of bacteria and fungi were established to see the impact of environmental factors on their multiplication and growth in the indoor air of the libraries.

2. Materials and methods

2.1. Study area

Jimma University is a public higher educational institution established in December 1999 by the amalgamation of Jimma College of Agriculture (founded in 1952), and Jimma Institute of Health Sciences (established in 1983). The two campuses are located in Jimma city, 352 km southwest of Addis Ababa with an area of 167 hectares. Currently a total of 28 583 students are enrolled in campus programs. The study included eight libraries of Jimma University, namely, Ketofurdessa Technology Library, Agriculture and Veterinary Medicine Library, Health Sciences Library, Social Science Library, Technology Library, Education Library, Law Library and FBE Library. The study was conducted between Aprils to May, 2013.

2.2. Sampling procedure

Bacteria and fungi measurement were made by passive air sampling technique: the settle plate method using 9 cm diameter Petri dishes. The sampling height which approximated to human breathing zone was 1 m above the floor and at the center of the room. Bacteria and fungi were collected on 2% nutrient agar and 4% sabouroad agar respectively. To obtain the appropriate surface density for counting and to determine the load with respect to time of exposure, the sampling times were set at 30, 60, 90 min. Moreover, samples were collected twice a day at 8:30 a.m. and 4:00 p.m. After exposure the sample were taken to the laboratory (Department of Environmental Health Science and Technology, Jimma University) and incubated at 37 °C for 24 h for bacteria and at 25 °C for 3 d for fungi.

Once colony forming units (CFU) were enumerated, CFU/m^3 were determined, taking into account the following equation described by Omeliansky[17,18].

$N = 5a\times10^4\ (bt)^{-1}$,

Where N=microbial CFU/m^3 of indoor air; a=number of colonies per Petri dish; b=dish surface (cm^2); t=exposure time (min).

Then, identification of isolates was done according to standard methods[19,20].

2.3. Statistical analysis

SPSS Statistics 16.0 software was applied to determine the likelihood of statistically significant differences between the concentrations of bacteria and fungi measured at different sampling place as well as the linearity between the concentrations of bacteria and fungi measured.

3. Results

The indoor air microbial loads of eight libraries of Jimma University were determined by taking 96 samples. The results of the research into the concentration, concentration range, arithmetic mean and standard deviation of bacterial and fungi aerosol present in the investigated libraries are presented in Table 1, 2, and 3. And also the type of microorganism isolated and microbial air quality standard of eight libraries are indicated in Table 4 and 5, respectively.

The results indicate that the highest bacterial CFU/m^3 air has been recorded at 8:30 a.m. in Health Science Library at 90 min exposure, which is 2 595 CFU/m^3, while the lowest bacterial CFU/m^3 air were recorded at 4:00 p.m. in Ketofurdessa Technology Library at 30 min exposure

Table 1

Number of bacterial CFU/m^3 air at different sampling time of day at different time of exposure.

Petri dish exposure time (Min)	Sampling time	Sampling sites							
		Ketofurdessa Technology Library	Agriculture and Veterinary Medicine Library	Health Science Library	Social Science Library	Technology Library	Education Library	Law Library	FBE Library
30	8:30 a.m.	498	1 101	2 123	760	1 887	1 415	1 153	1 625
	4:00 p.m.	367	944	1 887	682	1 573	944	865	1 389
60	8:30 a.m.	799	1 678	2 202	839	2 333	1 730	1 756	1 730
	4:00 p.m.	773	1 468	2 045	708	1 913	1 101	1 546	1 546
90	8:30 a.m.	856	2 097	2 595	865	2 429	1 992	1 844	1 879
	4:00 p.m.	830	1 905	2 525	751	1 975	1 538	1 651	1 782

Table 2

Number of fungi CFU/m^3 air at different sampling time of day at different time of exposure.

Petri dish exposure time (Min)	Sampling time	Sampling sites							
		Ketofurdessa Technology Library	Agriculture and Veterinary Medicine Library	Health Science Library	Social Science Library	Technology Library	Education Library	Law Library	FBE Library
30	8:30 a.m.	734	734	786	839	1 678	1 101	1 468	944
	4:00 p.m.	629	577	524	603	1 048	944	682	839
60	8:30 a.m.	891	1 258	839	1 035	1 809	1 861	1 494	1 022
	4:00 p.m.	904	944	603	813	1 114	1 586	826	891
90	8:30 a.m.	970	1 450	1 180	1 075	1 940	1 992	1 608	1 092
	4:00 p.m.	882	1 083	979	848	1 442	1 634	1 022	961

which is 367 CFU/m^3 (Table 1 and 3). The highest fungal CFU/m^3 air has been recorded at 8:30 a.m. in Education Library at 90 min exposure, which is 1 992 CFU/m^3, while the lowest fungal CFU/m^3 air were recorded at 4:00 p.m. in Health Science Library at 30 min exposure, which is 524 CFU/m^3 (Table 2 and 3).

Table 3

The range of microbe's distribution in Jimma University libraries.

	N	Minimum	Maximum	Mean	Std. Deviation
Bacteria CFU/m^3	48	367	2 595	1 476	582
Fungal CFU/m^3	48	524	1 992	1 087	381
Valid N (listwise)	48				

Table 4

Type of microorganism isolated from each Jimma University libraries.

Type of microorganisms isolate	Ketofurdessa Technology Library	Agriculture and Veterinary Medicine Library	Health science library	Social Science Library	Technology Library	Education Library	Law Library	FBE Library
Bacteria								
Micrococcus sp.	+	+	+	−	+	+	+	+
Staphylococcus aureus	+	−	+	+	+	−	+	+
Streptococcus pyogenes	+	+	+	+	+	+	−	−
Bacillus sp.	−	+	+	−	+	−	−	−
Neisseria sp.	−	−	−	−	+	−	−	+
Fungi								
Cladosporium sp.	+	−	+	−	+	+	+	+
Alternaria sp.	−	+	−	−	+	+	−	+
Penicillium sp.	−	+	+	+	+	+	+	−
Aspergillus sp.	−	−	+	+	−	−	+	+

Table 5

Evaluation of air quality in the designated areas of the Jimma University libraries according to the sanitary standards for non-industrial premises[20].

Group of microbes	Range of values (CFU/m^3)	Pollution degree	Sampling Sites and time															
			Ketofurdessa Technology library		Agriculture and Veterinary Medicine library		Health science library		Social Science library		Technology library		Education library		Law library		FBE library	
			8:30 a.m.	10 p.m.	8:30 a.m.	10 p.m.	8:30 a.m.	10 p.m.	8:30 a.m.	10 p.m.	8:30 a.m.	10 p.m.	8:30 a.m.	10 p.m.	8:30 a.m.	10 p.m.	8:30 a.m.	10 p.m.
Bacteria	< 50	Very Low	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	50−100	Low	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	100−500	Intermediate	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	500−2000	High	√	√	√	√	−	−	√	√	−	√	√	√	√	√	√	√
	>2000	Very high	−	−	−	−	√	√	−	−	√	−	−	−	−	−	−	−
Fungi	< 25	Very Low	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	25−100	Low	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	100−500	Intermediate	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	500−2000	High	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	>2000	Very high	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−

(√) In the range; (−) Not in the range

The scatter plots of bacteria versus fungi concentration, shows positive linear associations (P=0.001) with regression coefficient (R^2=0.22, n=48) as presented in Figure 1.

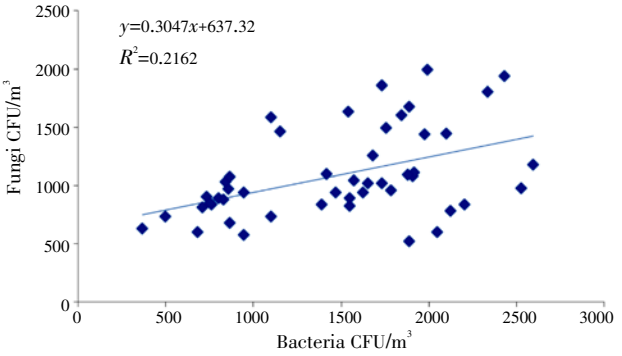

Figure 1. Scatter plots of fungal against bacteria concentration at libraries of Jimma University.

As can be seen in Table 4, the most isolated bacteria were *Micrococcus*, *Staphylococcus* and *Streptococcus*, whereas to a lesser extent *Bacillus* and *Neisseria* were isolated. The most detected fungi were filamentous species with aerial growth and fluffy, cotton-like appearance. Determination of properties such as size, shape, hyphal disposition and spore arrangement led to the results shown in Table 4 on the most common fungi.

4. Discussion

Microbiological quality assessment of indoor air study is one of the most vital investigations to determine the microbial indoor air pollution. The information on the indoor microbial concentrations of airborne bacteria and fungi is necessary both to estimate the health hazard and to create standards for indoor air quality control. The concentrations of bacterial and fungi aerosols in the indoor environment of Jimma University libraries, estimated with the use of the settle plate method, ranged between 367-2 595 CFU/m^3.

The concentrations of bacteria measured in all libraries were significantly different to each other (P=0.000). These can be mainly explained by the variation of density of occupant during sampling time as well as the variation of ventilation conditions[2,16]. In the Health Science Library, the highest CFU/m^3 might be due to the number of occupants during assessment relative to size of library which is around 13 times higher than the other libraries, whereas the lowest concentration were recorded at Ketofurdessa Technology Library that had the lowest density (0.06 occupant/m^2) than the others. These situations increase the shedding of bacteria and agitation of air. Similar studies revealed that, the presence of aerial bacteria was associated to the presence of personnel into the air of the partially closed premises[7,12]. The structural design and the low number of occupants per area might be responsible for low bacteria burden of Ketofurdessa Technology Library. Hence, an obvious practice to improve a more healthy quality of indoor air in the building would be to avoid overcrowding and to design good ventilation systems.

The concentrations of fungi measured in all libraries were significantly different to each other (P=0.000) like that of bacteria concentration. Although in some specific cases the values for fungi contamination were maintained during occupancy, its total mean concentration slightly decreased as occupation progressed, suggesting that most fungi species present in the air were not human-borne. Similar observations by others are in agreement with these data[12,13,21]. It thus seems likely that the dampness situation of the building might create favorable condition for the fungi contamination, which can be dispersed through droplets during disturbing and then maintained in aerial suspension. Hence, the most important means for avoiding adverse health effects is the prevention (or minimization) of persistent dampness and microbial growth on interior surfaces and in building structures.

In spite of their major source difference, the average fungi density found in the indoor air of libraries did appear to follow the same trend with bacterial concentration. This can be explained by the fact that the existed indoor air environmental factors of the libraries favor fungi and bacteria growth. As indicated in numerous studies, the environmental factors especially dampness enhance microbial growth and multiplication in the indoor atmosphere[2,16].

Thus, the microbial loads of the buildings were favored by the environmental conditions which enhance their development. And also it was stated by WHO that dampness situation has to be considered as the risk indicator for health risks of biological contaminants of indoor air[1].

A quantitative interpretation of the results describing the air quality in the library is difficult due to the lack of widely accepted normative and reference values. Universally applicable standards defining an acceptable level of indoor air contamination with microorganisms have not yet been established. Evaluation of the air quality in the designated areas on the premises of the libraries

in Jimma University was based on the sanitary standards for non-industrial premises formulated by the European Commission in 1993[22]. According to this classification, the air in the all libraries was in the range of highly or very highly contaminated with bacteria and fungi.

The air in the Ketofurdessa Technology Library, Agriculture and Veterinary Medicine Library, Social Science Library, Education Library, Law Library and FBE Library showed a similar level of contamination with bacteria. The other two, Health Science Library and the morning sample of Technology Library indicated high bacterial contamination. The results of the research into the concentration of mould fungi on the premises of the university library indicate that a high level of fungi contamination was determined in all libraries.

This remark, coupled to the fact that more than 14 m^3 of air is daily inhaled by a human adult[4] leads to the conclusion that the airborne microbial intake per day of the occupants of the analyzed building might likely exceed by at least 14-fold the average number of microorganisms expressed above. The control of the microbial load of the surrounding air is thus important to establish the quality and health conditions of the services rendered by any public institution.

The microbial isolates included five bacteria and four fungi which are *Micrococcus* sp., *Staphylococcus aureus*, *Streptococcus pyogenes*, *Bacillus* sp. and *Neisseria* sp. for bacteria isolates. The most isolated bacteria are Gram-positive cocci belonging to saprophytic microflora, generally associated to human skin and mucosa, thereby suggesting that the main bacterial contamination suspended in the indoor air derives from human presence.

The fungi isolates includes *Cladosporium* sp., *Alternaria* sp., *Penicillium* sp. and *Aspergillus* sp., in which they are recognized as opportunistic pathogens for humans and often associated with clinical manifestations of allergy, rhinitis, asthma and conjunctivitis. Also, these microorganisms are considered potential candidates involved in the establishment of sick building syndromes[23,24].

In Conclusion, almost all the libraries of Jimma University were heavily contaminated with bacteria and fungi. Thus, attention must be given to control those environmental factors which favor the growth and multiplication of microbes in indoor environment of libraries to safeguard health of users and workers. And also it needs to increase the size and the number of libraries in Jimma University, so as to make them sufficient for the current and future student population.

Conflict of interest statement

The authors declare that they have no conflict of interest.

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Comments

Background

Library is one of the important indoor places, where significant number of people spend their time daily. Therefore, air quality of the libraries should be optimal in terms of number of microbial contamination. Especially, presence of harmful microbes in the air should be avoided or at least their presence should be below their pathogenic level.

Research frontiers

Studies were carried out to determine the indoor air quality of eight libraries throughout the Jimma University. The study revealed that all eight libraries were contaminated in the range of high to very high bacterial and fungal contamination level.

Related reports

The number of occupants increases the shedding of bacteria and agitation of air increases the bacterial count in indoor environment (Meadow *et al*., 2013), whereas there is no effect in the fungal count due to the agitation or increase in occupancy (Soto *et al*., 2009).

Innovations and breakthroughs

This is a study done to access the microbial contamination level in indoor air. The study was conducted in eight different libraries.

Applications

The result showed that there is an immediate need to

improve the indoor air quality of all the libraries. One of the suggestions made by authors is to improve the room ventilation system.

Peer review

This study evaluated the indoor air quality of the eight different libraries through colony forming count method using both bacterial and fungal specific media. This is a simple and conventional way of microbial air quality assessment.

References

[1] World Health Organization. WHO guidelines for indoor air quality: dampness and mould. Copenhagen, Denmark: World Health Organization; 2009. [Online] Available from: http://www.euro.who.int/__data/assets/pdf_file/0017/43325/E92645.pdf. [Accessed on 24th November, 2013]

[2] Wamedo SA, Ede PN, Chuku A. Interaction between building design and indoor airborne microbial load in Nigeria. *Asian J Biol Sci* 2012; **5**: 183-191.

[3] Awad AH, Farag SA. An indoor bio-contaminants air quality. *Int J Environ Health Res* 1999; **9**: 313-319.

[4] Brochu P, Ducré-Robitaille JF, Brodeur J. Physiological daily inhalation rates for free-living individuals aged 1 month to 96 years, using data from doubly labeled water measurements: a proposal for air quality criteria, standard calculations and health risk assessment. *Human Ecol Risk Assess* 2006; **12**: 675-701.

[5] Hospodsky D, Qian J, Nazaroff WW, Yamamoto N, Bibby K, Rismani-Yazdi H, et al. Human occupancy as a source of indoor airborne bacteria. *PLoS One* 2012; doi: 10.1371/journal.pone.0034867.

[6] Qian J, Hospodsky D, Yamamoto N, Nazaroff WW, Peccia J. Size-resolved emission rates of airborne bacteria and fungi in an occupied classroom. *Indoor Air* 2012; **22**: 339-351.

[7] Meadow JF, Altrichter AE, Kembel SW, Kline J, Mhuireach G, Moriyama M, et al. Indoor airborne bacterial communities are influenced by ventilation, occupancy, and outdoor air source. *Indoor Air* 2014; **24**(1): 41-48.

[8] Bonetta S, Bonetta S, Mosso S, Sampo S, Carraro E. Assessment of microbiological indoor air quality in an Italian office building equipped with an HVAC system. *Environ Monit Assess* 2010; **161**: 473-483.

[9] Mandal J, Brandl H. Bioaerosols in indoor environment-a review with special reference to residential and occupational locations. *Open Environ Biol Monit J* 2011; **4**: 83-96.

[10] Huttunen K, Rintala H, Hirvonen MR, Vepsäläinen A, Hyvärinen A, Meklin T, et al. Indoor air particles and bioaersols before and after renovation of moisture-damaged buildings: the effect on biological activity and microbial flora. *Environ Res* 2008; **107**: 291-298.

[11] Kalogerakis N, Paschali D, Lekaditis V, Pantidou A, Eleftheriadis K, Lazaridis M. Indoor air quality-bioaerosol measurements in domestic and office premises. *J Aerosol Sci* 2005; **36**: 751-761.

[12] Soto T, Murcia RM, Franco A, Vicente-Soler J, Cansado J, Gacto M. Indoor airborne microbial load in a Spanish university (University of Murcia, Spain). *An Biol* 2009; **31**: 109-115.

[13] Soto T, Lozano M, Vicente-Soler J, Cansado J, Gacto M. Microbiological survey of the aerial contamination in urban areas of the city of Murcia, Spain. *An Biol* 2009; **31**: 7-13.

[14] Taubel M, Rintala H, Pitkaranta M, Paulin L, Laitinen S, Pekkanen J, et al. The occupant as a source of house dust bacteria. *J Allergy Clin Immunol* 2009; **124**: 834-840.

[15] Foarde KK, Dulaney P, Cole E, Van Osdell D, Ensor D, Chang J. Assessment of fungal growth on ceiling tiles under environmentally characterized conditions. *Indoor Air* 1993; **4**: 357-362.

[16] Graudenz GS, Oliveira CH, Tribess A, Mendes C Jr, Latorre MR, Kalil J. Association of air conditioning with respiratory symptoms in office workers in tropical climate. *Indoor Air* 2005; **15**: 62-66.

[17] Borrego S, Guiamet P, de Saravia SG, Batistini P, Garcia M, Lavin P, et al. The quality of air at archives and the biodeterioration of photographs. *Int Biodeterior Biodegradation* 2010; **64**: 139-145.

[18] Gutarowska B. Metabolic activity of moulds as a factor of building materials Biodegradation. *Pol J Microbiol* 2010; **59**: 119-124.

[19] Cheesbrough M. *Medical laboratory manual for tropical countries*. 2nd ed. Cambridge, UK: University Press Cambridge; 1991, p. 508-511.

[20] Rajash B, Rattan LI. *Essential of medical microbiology*. 4th ed. New Delhi: Jayppe Brothers Medical Publishers; 2008, p. 415-439.

[21] Ingold CT. *Fungal spores: their liberation and dispersal*. Oxford, UK: Clarendon Press; 1971.

[22] Commission of the European Communities. Indoor air quality and its impact on man. Report No. 12. Biological particles in indoor environments. Luxembourg: Commission of the European Communities; 1993.

[23] Schwab CJ, Straus DC. The roles of *Penicillium* and *Aspergillus* in sick building syndrome. *Adv Appl Microbiol* 2004; **55**: 215-238.

[24] Jones AP. Indoor air quality and health. *Atmos Environ* 1999; **33**: 4535-4564.